Safety in Mines Research Advisory Committee

Final Project Report

BRAKE TESTING OF TRACKLESS MOBILE MINING MACHINERY

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EXECUTIVE SUMMARY

The aim of this project is to develop an in-service brake testing specification for trackless mobile mining machinery of less than 50 ton. The primary output of this project is an in-service brake testing specification for trackless mobile mining machinery. Mines with trackless mobile mining machinery will use this specification for the testing and in-service verification of brakes as an input to maintenance to minimize the risk of brake system related accidents, preventing runaways of vehicles, thereby saving lives.

The status of brake testing of trackless mobile mining machinery in the platinum, iron ore and coal sectors was established by visiting different mines. An investigation into what exists worldwide was done focusing on brake test specifications as well as in-service verification of brakes. From the investigation, electronic brake testing equipment was recommended for the in-service testing of brakes. Different electronic brake testing equipment was evaluated on different vehicles to determine the usefulness of this type of equipment. These tests were conducted at Leeupan Collieries, Kumba. A brake testing specification for trackless mobile mining machinery was compiled.

At a workshop attended by interested parties from mining houses, original equipment manufacturers (OEM's), DME and SIMRAC the findings of the project were presented. The workshop accepted the proposed draft brake test specification with some minor modifications. The workshop recommended that the following should be included in the follow-up project (phase 2 of project SIM 040502):

- Evaluate the accuracy, repeatability and limitations of available electronic brake testing equipment.
- Include a risk assessment on the equipment.
- Determine the parameters of the proposed specification.
- Evaluate and modify the proposed specification.

The following recommendations were also made during the workshop:

- The DME will request the SABS to compile a part 2 of SABS 1589 specification to include hydrostatic drives.
- The brake testing specification should be included in the code of practice (COP) of mining operations.
- The DME should consider the inclusion of the brake testing specification in the mandatory code of practice of the DME.
- As a large percentage of vehicle accidents are caused by the operator (human factor) and not mechanical failure, SIMRAC should consider a project to address this problem.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Safety in Mines Research Advisory Committee (SIMRAC) for financial support of project SIM 040502 and also for the interest and technical input of the SIMRAC Technical Committee. The team would also like to thank the personnel of Leeupan Colleries for their assistance during the evaluation of the electronic test equipment.

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1 INTRODUCTION

Most accidents due to brake failure can be attributed to an inadequate brake system on the vehicle, inadequate maintenance or overloading of the brake system when driving downhill or downdip at too high a speed or gear. To reduce these accidents vehicles have to be fitted with brake systems that can handle the operational requirements and have efficient maintenance with in-service testing of the brake system. No definitive procedure and supporting equipment exist in the South African mining industry to evaluate the efficiency of braking systems on trackless mobile mining machinery.

The different levels of brake testing that exist are daily checks by the operator, intermediate tests and system verification testing. The intermediate testing is the in-service verification of the brakes as an input to maintenance. This project focuses on the intermediate tests that are performed at regular intervals.

This is the final report on phase 1 of project SIM 040502 on brake testing of trackless mobile mining machinery.

2 METHODOLOGY

The following methodology was followed during this project:

- The status of brake testing of trackless mobile mining machinery in the platinum, iron ore and coal sectors was established. Different mines where visited to establish what testing and in-service verification is done. The operational condition and the type of brake equipment on the different vehicles was also established.
- An investigation into what exists worldwide was done. The investigation focused on brake test specifications as well as in-service verification of brakes. Land Mobility Technologies (LMT) was responsible for this part of the study.
- Different brake testing equipment was evaluated on different vehicles and at varying operating conditions to determine the usefulness of this type of equipment. These tests were conducted at Leeupan Collieries, Kumba.
- A brake testing specification for trackless mobile mining machinery was drawn up taking the results of the studies into brake testing specifications and the testing of brake testing equipment into account. The emphasis of the specification was on practicality and cost effectiveness on the tests.
- A workshop was held with industry and manufacturers of trackless mobile mining machinery. Representatives of the DME and SIMRAC were also present at this workshop. During this workshop the findings of the project were presented and the proposed draft brake testing specification was discussed. The draft brake testing specification was accepted with some minor modifications.
- The draft brake testing specification as accepted by the workshop was circulated to all interested parties for comments. No comments were received.
- The final project report was compiled.

3 STATUS IN SOUTH AFRICAN MINING

3.1 Visits to mines

3.1.1 Questioner

A questioner was circulated to mines to determine the type, size and number of vehicles used in industry. This questioner was circulated through the technical committee of SIMRAC. No feedback was however received.

3.1.2 Visits

Different mines were visited to determine the different trackless mobile mining machinery and brake systems used in South African mines, to assess what brake testing is being done and to determine how big the problem of brake failures is. Appendix A summarises the information gathered during these visits. The different mines were selected from different sectors using large numbers of trackless mobile mining machines. The following mines were visited:

Name	Town	Mining sector
• Waterval Business Unit UG2	Rustenburg	Anglo Platinum
• Kumba Resources	Thabazimbi	Iron
• Kumba Resources	Delmas	Coal

3.1.3 Brake testing

Brake testing of varying degrees and quality is being done on all mines. The following tests are performed:

Daily check:

- Application and release of brake system to test functionality.
- Test the brakes on a ramp.

Tests at certain intervals (weekly or after certain engine hours):

- Visual checks for wear of brake parts and leaks.

No system tests are performed on brake systems. It is accepted that the vehicles are equipped with adequate braking systems.

Workshop managers at the mines expressed the need for a test or test procedure to test braking systems at intermediate intervals to determine maintenance requirements. The need for a test standard or procedure for testing the braking of hydrostatic drive vehicles was also expressed.

3.2 SAMRASS database

The SAMRASS database was searched for vehicle related accidents. The information received only shows the number of injuries and casualties. No details concerning the causes of the accidents to determine which incidents are brake failure related could be gathered from the database. To determine which incidents are brake failure related, the accident report files have to be accessed at the regional offices.

3.3 Braking systems used

During the visits to the mines the different braking systems used by trackless mobile mining machinery were also assessed. Van den Ordel (2004)(Anglo Platinum) also summarised the braking systems used by trackless mobile mining machinery. The following braking systems are used by trackless mobile mining machinery:

Production machines (LHDs) and dump trucks:

Pneumatic (air) brake system.
Disc brakes.
Fully enclosed liquid cooled brakes (LCB).
Spring applied hydraulic release brakes (SAHR).

Utility type vehicles:

Liquid cooled brakes (LCB) on conventional axle vehicles.
Hydrostatic drive configuration with spring applied hydraulic release emergency/park brake.
Combination of conventional axle and hydrostatic drive.

Light commercial and logistic support vehicles:

Dual circuit brake master cylinder assisted by a vacuum brake servo (booster), which activates front disc brakes, and rear drum brakes.
Vacuum applied spring release (VASR).

3.4 Requirements for brake test specification

From consultation with workshop managers of mines and experts in the field of brake testing a list of requirements for the required brake test specification was compiled.

Requirements for a brake test specification:

- In-service testing of trackless mobile mining machinery used in South African mines.
- Operational tool to indicate maintenance requirement (input to maintenance).
- Intermediate test intervals (weekly or as prescribed by manufacturer) not daily check or complete system testing.

- No diagnostic tool.
- Cost effective.
- Time effective.
- Independent of type of brake system.
- Ease of implementation and use.

4 INVESTIGATION INTO WHAT EXISTS

An investigation into what exists in the field of brake testing worldwide was done. The investigation focused on brake test specifications as well as in-service verification of brakes. The aim of this literature study was to gather as much information as was possible on braking tests and standards of heavy vehicles. The expertise and contacts of LMT were utilized in this part of the project.

4.1 Specifications

This literature study evaluated existing braking standards applicable to off-road mining machines. As almost all the applicable standards have some commonality with ISO 3450:1985 only the ISO 3450:1985 specification is discussed in following the paragraphs. The SABS 1589:1994 specification is also largely based on ISO 3450:1985. A section covering hydrostatic drives is however absent in SABS 1589:1994. In Appendix B the literature study with descriptions of the relevant specifications and standards is attached.

The New South Wales “Guideline on the requirements for the design, installation, testing and maintenance of braking systems fitted to free-steered vehicles in underground coalmines” is also discussed in paragraph 4.1.2.

4.1.1 ISO 3450:1996

This standard specifies minimum braking performance and test criteria for brake systems of self-propelled, rubber-tired loaders, tractors, graders, backhoe loaders, tractor-scrapers, excavators and dumpers. These earth-moving machines can either operate on work sites or travel on public roads. Service-, secondary- and parking brakes are also covered by this standard.

This standard states that if stored energy is used for the service brake system, that the system shall be equipped with a warning device which automatically activates should the energy level drop below 50% of the maximum value specified.

Two test mass configurations are specified. All vehicles excluding dumpers and tractor-scrapers should be loaded to GVM. Brake tests for dumpers- and tractors- should be conducted where the test mass should be GVM minus payload.

Burnishing (or running in) of the vehicles brakes is allowed prior to testing. Retarders may not be used in the service brake test but are allowed when testing the secondary brakes.

This standard requires a hard, dry surface with a gradient of less than 1% in the direction of travel to be used for testing all vehicles, excluding rigid-frame and articulated steer dumpers with a mass above 32 ton. The test course for rigid frame vehicles or articulated steer dumpers with a mass above 32 ton should have a downward slope of 9 ±1% in the direction of travel.

The brake test will be done from a speed equivalent to 80% of the vehicles maximum speed (on level ground) if its maximum speed is above 32 km/h or else at the vehicles maximum speed. (This does not apply to rigid-frame and articulated steer dumpers with a mass above 32 ton).

i. *Cold test*: Beginning with cold brakes, the service- and secondary brake system stopping distance tests shall be conducted twice while travelling forward, once in each direction of the test course with at least 10 min between stops. The stopping distance and vehicle speed should be the average of the two tests. Both the service- and the secondary brake system should stop the machine within the stopping distance specified in Table 2 and Table 3 of Figure 4-1.

Table 2 — Stopping distance performance — Machines tested without payload

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{150} + 0,2(v + 5)$	$\frac{v^2}{75} + 0,4(v + 5)$
NOTE — $v > 0$ and measured in km/h (see 7.6.1.1).	

Table 3 — Stopping distance performance — Machines tested with payload except rigid frame or articulated dumpers with a machine mass over 32 000 kg

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{44} + 0,1(32 - v)$	$\frac{v^2}{30} + 0,1(32 - v)$
NOTES 1 $v > 0$ and measured in km/h (see 7.6.1.1). 2 The term $0,1(32 - v)$ is deleted from the formula for speeds over 32 km/h.	

Figure 4-1:Service and secondary brake system stopping distance requirements

ii. *Heat fade test*: The service brakes must complete four consecutive stops at the vehicles maximum deceleration without sliding the tires. After each test the initial machine speed must be reached using maximum acceleration, prior to the next brake test. A fifth consecutive stop shall be executed and the stopping distance shall not exceed 125% of the value determined from the cold test.

iii. *Holding performance*: The machines must be tested in both the forward and the reverse direction. The service brake should be capable of holding the machine on a 25% slope (This test does not apply to rigid-frame and articulated steer dumpers with a mass above 32ton). The parking brake should be capable of holding the machine, depending on its class (refer paragraph 7.5.2 of standard), on either a 15% slope or a 20% slope. If the slope tests are impractical, a tilt-surface with slip-resistant surface may be used or a horizontal pulling force may be applied to the stationary vehicle with its brake applied and with the vehicle standing on a level surface. The horizontal pulling forces that are equivalent to the different slope values are given in paragraph 7.5.3.b of the standard.

iv. *Stopping performance for rigid frame and articulated steer dumpers over 32 ton:* The test course should have a downward slope of 9 ±1% slope in the vehicle direction of travel, as stated previously. The service brakes shall be tested by five consecutive stopping tests with 10 to 20 min intervals between stops from a machine speed of 50±3 km/h or the vehicle's maximum level surface speed if less. The stopping distance shall not exceed the values specified in Table 4 of Figure 4-2. The secondary brake system shall be tested by means of a single stopping test carried out from a machine speed of 25±2 km/h. If the vehicle is fitted with a retarder, it may be used prior to and during the test. The stopping distance may not exceed that specified in Table 4 of Figure 4-2.

Table 4 — Stopping distance performance — Rigid frame and articulated steer dumpers with a machine mass over 32 000 kg

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{48 - 2{,}6\,\alpha}$	$\frac{v^2}{34 - 2{,}6\,\alpha}$
NOTE — $v > 0$ and measured in km/h (see 7.7.2.1). α is the slope as a percentage.	

Figure 4-2: Service- and secondary brake system stopping distance requirements

The results of the stopping tests should then be summarised in a report containing the information as discussed in paragraph 8 of the ISO standard.

This ISO standard is useful in evaluating the machines brakes when new or after scheduled maintenance to the vehicle but these tests are too time consuming to execute on a regular basis.

4.1.2 New South Wales: Guideline on braking systems

The New South Wales guideline on braking systems specifies the requirements for the design, installation, testing and maintenance of braking systems fitted to free-steered vehicles in underground coalmines. The guideline is intended for manufacturers, service/maintenance organisations, users and regulatory authorities concerned with the safety of free-steered vehicles when operated in underground coalmines. The guidelines distinguish between routine testing and in-service testing.

For in-service testing the guidelines list the following information to be recorded:

(i) The speed immediately prior to the application of the brakes (km/h)

(ii) The mean deceleration rate (m/s^2)

(iii) The response time between the application of the brakes and the beginning of retardation. The beginning of retardation is considered to be 10% of g.

(iv) The operating force applied to the pedal/button/lever by the operator.

Any brake testing instrument to be employed has to demonstrate compliance with the guideline and shall be calibrated accordingly:

.

Accuracy	± 1.5% g
Repeatability	± 2.0% g
Range	0 - 140% g (g = 9.81 m/s^2)
Pedal force transducer	0 - 2000 N
Calibration	± 0.1% g

The New South Wales guideline on braking systems gives useful guidelines on brake testing and the equipment used for brake testing. The guideline is attached as Appendix C.

4.1.3 Conclusions from specification survey

From the different specifications and standards that were surveyed the following can be concluded:

- It is concluded that most of the braking standards and recommended practices evaluated in this study are related to the well-known ISO 3450:1985 standard.

- Almost all of the standard test procedures are useful for the manufacturers of the vehicles but are impractical for in-service brake evaluation.
- The New South Wales: Guideline on braking systems gives practical guidelines for in-service testing of brake systems.
- The differing working conditions and applications of the mining machines will make it difficult to create a single applicable global braking standard.

4.2 Test equipment

Different test equipment and methods of brake testing and their merits are briefly discussed in this paragraph.

4.2.1 Rolling road tester

The rolling road tester or rolling road dynamometer is widely used for brake testing for roadworthy certificates of vehicles. This equipment is very expensive and causes many arguments as the coefficient of friction on the rollers varies with years of service and wear. The rolling road tester will be too expensive for general use in mines.

4.2.2 Multi- Plate Performance-Based Brake Tester:

The Multi-Plate Performance-Based Brake Tester is being tested for use by commercial vehicle operators and vehicle and engine research laboratories of the National Transportation Research Centre (NTRC). The apparatus consists of a platform over which a tractor-trailer rig can be driven so that it can be weighed in a few seconds. To test the brakes, the driver is asked to drive the truck onto the platform at 16 km/h to 32 km/h and brake sharply before leaving the apparatus. The platform, which is 24 m long, consists of 48 steel plates laid down in pairs, each of which measures about 1 m by 1.2 m. Underneath each steel plate are sensor rods with transducers that convert the mechanical forces of the moving truck to corresponding electrical signals. As a truck rolls over the platform, the sensors measure the weight and horizontal force on each plate as the wheels come to a stop. The braking force is related to the pressure exerted on the plates by each truck wheel during deceleration and stopping. This could work for road test stations but would be difficult to implement in the mining industry because a test platform would have to be installed on each level in the mine and the surface is almost never perfectly level. The equipment is also too expensive for general use in mines.

4.2.3 Ramp

The vehicle is driven on a ramp (decline) and the brakes applied. If the vehicle moves the brakes are suspect and need to be checked. To prevent runaway of the vehicle when the brakes fail, the ramp is often built with an upturn (incline) at the bottom to catch the vehicle. This test is widely used to test emergency brakes. For the testing of service brakes the ramp has to be long, which makes it impractical. This test is not really applicable for service brakes and the space needed for the ramp may be a problem in a mine.

4.2.4 Stopping distance

Two markers are placed a distance equal to the maximum stopping distance for the vehicle apart. The vehicle is driven at the correct speed and the brakes are applied at the first marker. If the vehicle stops before the second marker the brakes are OK. If the vehicle stops beyond the second marker the brakes are inadequate and have to be checked. This test is dependant on a number of variables (correct vehicle speed, road surface, and application of brakes at correct time), which make the test unreliable. This test can however be successfully implemented for the daily operator check.

4.2.5 Mechanical brake test meter

A mechanical retardation meter consists of a finely balanced pendulum free to respond to any changes in the speed or angle, working through a gear train to rotate a needle round a dial. To damp out all the vibrations, the instrument is filled with a special fluid not sensitive to changes in temperature. The dial is calibrated in percentage “g”. Bowmonk Ltd. (http://www.bowmonk.com) markets such a mechanical brake test meter. See Appendix E. The mechanical brake tester is robust and easy to use. Data logging must however be done manually, which makes record keeping more cumbersome. To be able to compare tests similar road surface conditions have to be used.

4.2.6 Electronic brake testing equipment

There are a number of electronic brake test measuring equipment suppliers in South Africa. Turnkey Instruments (http://www.turnkey-instruments.com) is probably the most renowned for their SIMRET instruments. Two other companies that also supply similar devices are WABCO Automotive (http://www.bowmonk.com) and Brakecor. Product brochures of the SIMRET instruments are supplied in Appendix C and that of Brakecor in Appendix D. Wabco is the local agents for Bowmonk instruments and some information on their products is supplied in Appendix E.

The use of electronic brake testing equipment has the following advantages:

- By logging this brake test data, the fleet manager will be able to pick-up a degradation of the vehicles brake system and preventative maintenance can be scheduled and possible accidents due to brake failure prevented.

- The system keeps record of the tests which means that the vehicles brake performance can be trended
- It is a relatively quick test.
- Only one instrument is required per workshop.

4.2.7 Conclusions from test equipment survey

The different test equipment available as described in the previous paragraphs were evaluated against the requirements for the brake tests specifications. The electronic and mechanical brake testers are most suited for the regular brake testing to be used as an input to maintenance. The electronic brake testers are recommended as they have the added advantage of record keeping and trending.

4.3 Evaluation of available electronic testing equipment

The investigation into what exists worldwide on brake test specifications as well as in-service verification of brakes led to the use of portable brake testers for in-service brake testing. The possibility of using this equipment was evaluated at Leeupan Colleries of Kumba. The Simret, Wabco and Brakecore test equipment was evaluated. The brake testers were used on the following equipment and conditions:

- Vehicles: 1 ton, 40 ton ADT (empty, 40% payload and 70% payload) and wheel bucket loader.
- Gravel road: Level, incline and decline.
- Tar road.

This preliminary evaluation of the electronic brake testers has shown that brake testers can be used for in-service evaluation of brakes. Figure 4-1 shows an example of the results of the tests and figure 4-2 shows a photo of the test equipment in the vehicle. In Appendix F the full set of results of the preliminary evaluation of the electronic brake testers is shown. The tests have also shown that trending purposes the tests can be done on an empty vehicle. By logging this brake test data, the fleet manager will be able to pick-up a degradation of the vehicles brake system and preventative maintenance can be scheduled and possible accidents due to brake failure prevented.

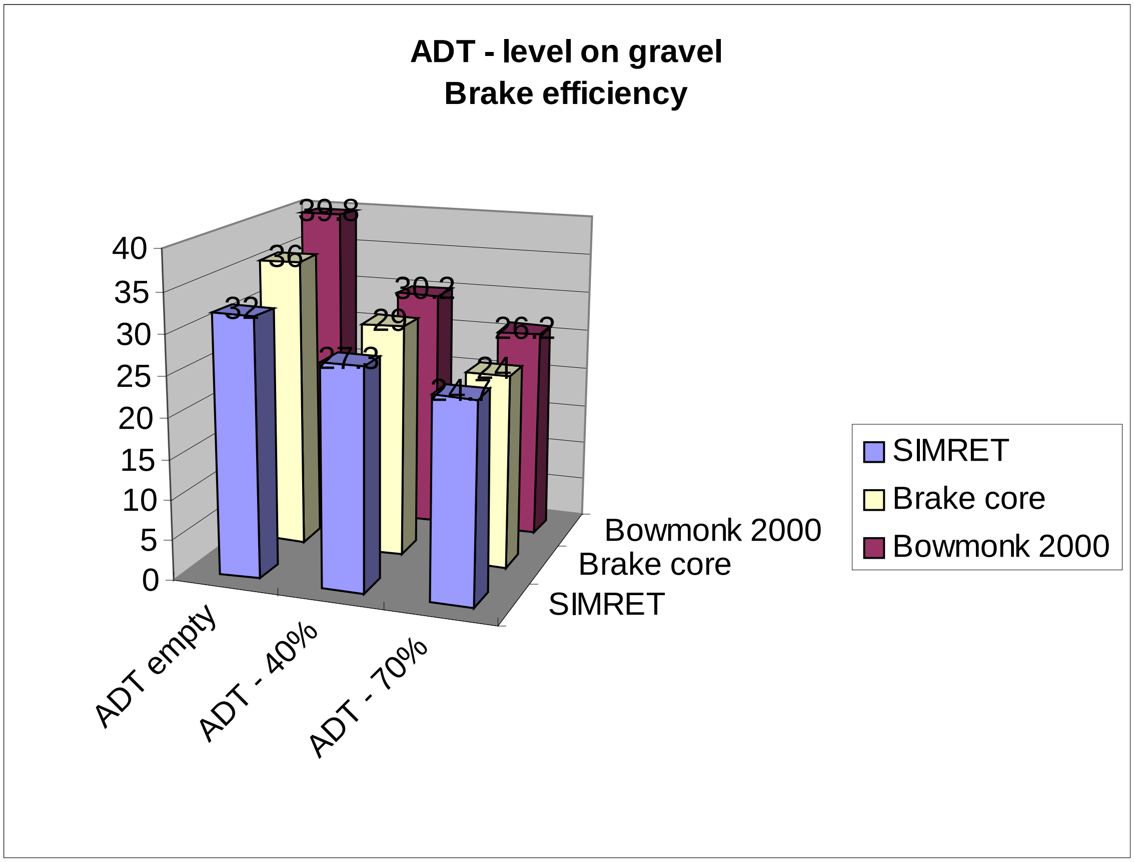

Figure 4-1 Brake efficiencies on level gravel road for the 40 ton ADT

Figure 4-2 Photo of test equipment in vehicle

5 SPECIFICATION

5.2 Draft specification

A draft specification making use of electronic brake testing equipment as described in paragraphs 4.2.6 and 4.3 was compiled. This draft specification was then discussed at the workshop with industry (see paragraph 5.2). Certain modifications were proposed at the workshop and the specification was accordingly modified. The modified specification was then circulated to all interested parties, who attended the workshop for comments. Table 5-1 shows the draft specification and table 5-2 lists the recommended information to be recorded on the test sheet. Figure 5-1 shows an example of a test sheet.

PROPOSAL FOR BRAKE TESTING OF RUBER TYRED MINE VEHICLES

PURPOSE

To ensure that the braking effort of a vehicle is adequate for the safe and efficient operation of the vehicle. To be used as an input for maintenance.

SCOPE

Applicable to all rubber tyre vehicles (mechanical and hydrostatic drive), but excluding motorcycles and builder's dumpers

REFERENCES

1. ISO 3450:1985
2. SABS 1589:1994

EQUIPMENT USED

Dynamic brake testing equipment i.e.: Simret or equivalent

RESPONSIBILITY

Workshop foreman
Diesel Mechanic

METHOD

1. Service brakes (Static testing) – all vehicles

Vehicles with mechanical drive systems. The Operator/driver of the vehicle will:

1.1 On a flat surface, start the engine and let the air or hydraulic pressure and temperature build up to the operating conditions. This must occur within the recommended period of time.

1.2 Release the emergency and park brakes.

1.3 Select the neutral position in the transmission.
1.4 Fully apply the service brake.
1.5 Select first gear in the transmission.
1.6 Increase the engine speed to recommended revolutions per minute. The vehicle must not move.
1.7 Do not use the vehicle if it moves, but report to his supervisor or to the relevant workshop.

Vehicles with Hydrostatic drive systems: Test according to recommendations of vehicle manufacturer.

2. Emergency brake (Static testing) – all vehicles

Vehicles with mechanical drive systems. The operator/driver of the vehicle will on a flat surface:
2.1 Start the engine,
2.2 Select the neutral position in the transmission, and
2.3 Let the air pressure build up to operating pressure. This must happen in the recommended period of time.
2.4 Select first gear in the transmission
2.5 Increase the engine speed to 50% of maximum revolutions per minute. The machine must not move.
2.6 Do not use the machine if it moves, but report to the relevant workshop,

Vehicles with Hydrostatic drive systems: Test according to recommendations of vehicle manufacturer.

NB: The sequence of the test may vary depending on the type of equipment

3. Dynamic test using Simret Tester or similar – Service brakes and park brakes
3.1 Artisan or designated test person will conduct all dynamic brake tests.
3.2 Dynamic brake tests will be carried out at a specified interval like on a weekly basis; on each service (excluding daily services) and after any intervention, repairs or adjustments have been carried out on braking systems. As per the code of practice of the mine.
3.3 The brakes will be tested as detailed in section 1 of this work instruction before carrying out the dynamic test.
3.4 Dynamic tests will be carried out on a dry surface, with an empty vehicle. Make sure that the testing surface will remain approximately constant over a period of time
3.5 Set up the tester as detailed in the manual.
3.6 Travel the machine at the speed as specified in SABS 1589 or at the highest speed possible if the speed cannot be achieved and apply the service brakes.
3.7 Allow the instrument to calculate the braking effort.
3.8 Compare the brake efficiency with the new brake value (blue printed value) for the specific vehicle. If there is a reduction of more than x%

	(parameter to be determined during follow-up project) the vehicle must be reported and inspected.
3.9	If the brake efficiency drops below x% (parameter to be determined during follow-up project) the vehicle must be withdrawn from service and be repaired.
3.10	Compare the brake system reaction time with the new brake value (blue printed value) and if there is a reduction of more than x% (parameter to be determined during follow-up project) the vehicle must be inspected and repair (System check).

Table 5.1 Proposed brake testing specification

INFORMATION TO BE RECORDED ON TEST SHEET:
1. Vehicle type
2. Vehicle registration
3. Date
4. Km reading
5. Engine hour reading
6. Type of braking system
7. Test equipment
8. Brake wear indicator (brake lining thickness)
9. Service brake static test: Yes/No
10. Park brake static test: Yes/No
11. Service brake dynamic test:
Reaction time
Brake efficiency
12. Name of test official

Table 5.2 Recommended information to be recorded on test sheet.

EXAMPLE OF AN INSPECTION SHEET

Vehicle type			**Vehicle registration**		
Date			km		
Test equipment					
Service brake Static testing	Yes	No	Park brake Static testing	Yes	No
Service brake Dynamic testing	Brake efficiency		Park brake Dynamic testing	Brake efficiency	
	Map value	Actual (-10% no go)		Map value	Actual (- 10% no go)
Service brake Dynamic testing	Brake system reaction		Park brake Dynamic testing	Brake system reaction	
	Map value	Actual (- 5% no go)		Map value	Actual (- 5% no go)
Dynamic test without test equipment	Stopping distance				
	Map value	Actual			
Tested by			Signature		

Figure 5-1 Example of an information sheet

5.3 Workshop with industry

A workshop was held on the 17th of November 2004 on the findings of the project. Interested parties from mining houses, Original Equipment Manufacturers (OEM's), the DME and SIMRAC attended the workshop. A presentation was given on the findings of the project including the literature and standards study, the preliminary evaluation of the electronic brake testing equipment and the proposed draft brake test specification. The following results and recommendations came out of the workshop:

5.3.1 Conclusions:

The following conclusions were reached at the workshop:

- The workshop confirmed the recommendation to actively use dynamic brake testing.
- The proposed test specification for brake testing was accepted with certain modifications. (See paragraph 5.2.3).
- The proposed test specification addresses the intermediate brake testing and not daily checks or brake system verifications. (See paragraph 5.2.2).
- The parameters of the test specification have to be determined. (See paragraph 5.1).
- The SABS specification (SABS 1589:1994) needs revisiting to include hydrostatic drives.
- Different standards will have to be set for different categories of vehicles. One suggestion is that the categories be determined on the weight of the vehicle.

5.3.2 Levels of brake testing:

It was affirmed that different levels of brake testing do exist. This project only addresses the intermediate interval brake testing. The following levels of brake testing were discussed:

- Daily check by operator.
- Intermediate tests: Weekly or at any other specified intervals like 500-hour service. This test interval must be equipment related. This test should be used as input to maintenance requirements. This project addresses this test.
- System certification test, which needs to be done after a major overhaul or modification of the brake system. (SABS 1589: 1994 or ISO 3450:1996).

5.3.3 Specification:

The proposed draft specification was discussed and the following modifications were recommended (see paragraph 5.1 for the amended draft specification):

- Scope: Include hydrostatic and mechanical drive.
- Service brakes (Static testing) (Point 1):

  Daily Check.

  Proposed procedure only valid for mechanical drive vehicles.

Hydrostatic drive vehicles: Test according to recommendations of vehicle manufacturer.

Point 1.1: Include build up of operating temperature.

Point 1.6: Increase the engine speed to recommended revolutions per minute.

System pressure must build up within recommended period.

- Emergency brake (Static testing) (Point 2):

  Daily Check.

  Proposed procedure only valid for mechanical drive vehicles.

  Hydrostatic drive vehicles: Test according to recommendations of vehicle manufacturer.

- Dynamic test using electronic brake testing equipment (Simret or similar device) – Service brakes and park brakes (Point 3):

  Point 3.1: Dynamic brake tests will be carried out at a specified interval like on a weekly basis or after certain engine hours; on each service (excluding daily services) and after any intervention, repairs or adjustments have been carried out on braking systems.

  Point 3.6: Travel the machine at the required speed as specified in SABS 1589, or at the highest possible speed if the required speed cannot be achieved.

- Dynamic test without test equipment – all vehicles (Point 4);

  The workshop recommended taking this option out of the specification. If the operation does not have a brake tester the service can be contracted in.

- Inspection sheet:

  List required information to be recorded on a test sheet. No format will be prescribed. An example should however be supplied.

5.3.4 Recommendations:

The following recommendations were made by the workshop:

- The DME will request the SABS to compile a part 2 of SABS 1589 specification to include hydrostatic drives.
- The brake testing specification should be included in the code of practice (COP) of mining operations.

The DME should consider the inclusion of the specification in the mandatory code of practice of the DME.

- As a large percentage of vehicle accidents are caused by the operator (human factor) and not necessary mechanical failure, SIMRAC should consider a project to address this problem.

The following recommendations concerning the follow-up phase of the current project were made. Phase 2 of project SIM 040502 should include the following:

- Evaluate the accuracy, repeatability and limitations of available electronic brake testing equipment.
- Include a risk assessment on the electronic test equipment.
- Determine the operating parameters of the proposed specification.
- Evaluate and modify the proposed specification.

6 CONCLUSION AND RECOMMENDATIONS

An in-service brake testing specification for trackless mobile mining machinery was developed during this project. Mines with trackless mobile mining machinery will use this specification for the testing and in-service verification of brakes as an input for maintenance to minimize the risk of brake system related accidents, preventing runaways of vehicles, thereby saving lives.

The status of brake testing of trackless mobile mining machinery in the platinum, iron ore and coal sectors was established by visiting different mines. An investigation into what exists worldwide was done focusing on brake test specifications as well as in-service verification of brakes. From the investigation electronic brake testing equipment was recommended for the in-service testing of brakes. Different electronic brake testing equipment was evaluated on different vehicles to determine the usefulness of this type of equipment. These tests were conducted at Leeupan Collieries, Kumba. A brake testing specification for trackless mobile mining machinery was compiled.

At a workshop attended by interested parties from mining houses, Original Equipment Manufacturers (OEM’s), the DME and SIMRAC the findings of the project were presented. The workshop accepted the proposed draft brake test specification with some minor modifications. The workshop recommended that the following aspects should be included in the follow-up project (phase 2 of project SIM 040502):

- Evaluate the accuracy, repeatability and limitations of available electronic brake testing equipment.
- Include a risk assessment on the electronic test equipment.
- Determine the operational parameters of the proposed specification.
- Evaluate and modify the proposed specification.

The following recommendations were also made during the workshop:

- The DME will request the SABS to compile a part 2 of SABS 1589 specification to include hydrostatic drives.
- The brake testing specification should be included in the code of practice (COP) of mining operations.
- The DME should consider the inclusion of the brake testing specification in the mandatory code of practice of the DME.
- As a large percentage of vehicle accidents are caused by the operator (human factor) and not necessary mechanical failure, SIMRAC should consider a project to address this problem.

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APPENDIX A

INFORMATION GATHERED DURING MINE VISITS

APPENDIX B

LITERATURE STUDY

APPENDIX C:

NEW SOUTH WALES: GUIDELINES ON BRAKING SYSTEMS

APPENDIX D:

TURMKEY INSTRUMENT’S BRAKE TEST EQUIPMENT

APPENDIX E:

BRAKECOR'S BRAKE TEST EQUIPMENT

APPENDIX F:

WABCO’S BRAKE TEST EQUIPMENT

APPENDIX G:

EVALUATION RESULTS OF ELECTRONIC BRAKE TESTING EQUIPMENT